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RELATIONSHIPS BETWEEN DISTRIBUTION OF TESTACEA (PROTOZOA, RHIZOPODA) AND THE SOIL HABITAT

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Résumé

Une comparaison de la composition faunistique des thécamoebiens de huit sols montagneux montre que trois différents groupes d'habitats sont caractérisés par des espèces particulières de thécamoebiens. Le groupe 1 consiste en deux milieux tourbeux de type «fen» (sols organiques du type humisol hydrique) caractérisés par trois espèces: *Hyalosphenia elegans, Arcella discoides* et *Euglypha strigosa.* Le groupe 2 réunit deux sols de forêt de conifères (podzols) et est représenté par une espèce: *Corythion dubium,* une espèce endogée fréquente atteignant une densité maximale en sol forestier. Le groupe 3 comprend les quatre derniers habitats (sols de transition) et représenté par deux espèces: *Plagiopyxis callida,* une espèce terricole typique, et *Euglypha polylepis,* une espèce peu fréquente. L'acidité semble jouer un rôle négligeable dans les variations de la composition et de la distribution des espèces des sols étudiés. Le nombre d'espèces terricoles accroît avec la profondeur alors que le nombre d'espèces à thèque pyriforme décroît.

Abstract

Comparative studies of the species lists of Testacea for 8 mountain soils show that three different groups of habitats are characterized by particular species of Testacea. Group 1 consists of the two fen habitats (hydric humisol organic soils) characterized by three species: *Hyalosphenia elegans, Arcella discoides* and *Euglypha strigosa.* Group 2 consists of the two coniferous forest soils (podzols), represented by one species, *Corythion dubium,* a common soil species reaching maximum numbers in forest soils. Group 3 consists of the remaining four habitats (transition soils), represented by 2 species, *Plagiopyxis callida,* the typical terricolous species, and *Euglypha polylepis,* a very sparse species. Acidity seems to play a negligible role in variations in species composition and distribution in the various soils studied. The number of species was influenced by the degree and the permanence of wetness of habitat. The number of terricolous species increased with profile depth while the number of species with pyriform tests decreased.

Introduction

Soil protozoa live in environments resulting from the interaction of climate, vegetation and soil type, but abiotic factors seem to affect Protozoa most through the vegetation. Most soil Protozoa tend to be eurythermal and can tolerate a variety of geochemical conditions. Temperature affects soil Protozoa by influencing the type of vegetation, the decomposition rate of its litter and the soil type. Soil type likewise can affect Protozoa through soil porosity, which affects moisture fluctuations, and by geochemistry, which influences the kind of vegetation that can grow and regulates the rate of litter decomposition (Bocock *et al.*, 1960).

Generally there tends to be a broad distinction in the protozoan fauna between fast growing species susceptible to rapid population fluctuations, such as the small amoebae, flagellates and ciliates, and slow growing species which show relatively slow population changes, such as the larger amoebae, ciliates and many Testacea. If the zonal distribution of these two groups is considered in relation to the organic cycle of the soils then the fast-growing group is dominant in soils of high productivity with a high organic turnover, and in soils in which organic breakdown is characterized by short periods of greatly accelerated decomposition (Stout, 1965). These include tropical and warm temperate mineral soils, and the sub-alpine and sub-polar soils. The slow-growing group, conversely, is dominant in soils of relatively low productivity and with a low level of mineralization in which there tends to be a slow but steady rate of organic breakdown (Stout, 1965). These include organic soils, peats and many forest litters, and soils of cool to cold climates. In the extreme conditions of deserts, whether tropical or polar, biological activity is so effectively restricted by lack of moisture or low temperature that the fast-growing group is better able to profit from the very limited periods of organic activity.

Although many species of Testacea are quite cosmopolitan, they occur with different frequency under different soil types, soil horizons and soil conditions. Of all protozoans, the testates exhibit a much greater distinction between habitats and factors influencing such distribution are clearly different. Usually such factors as vegetation, amount of soil moisture and pH may have the greatest effect on testacean distribution and community structure (Chardez and Delecour, 1970; Coûteaux, 1969; Heal, 1961; Rosa and Lhotsky, 1971), and on test size and morphology (Heal, 1961). However, other factors are important. In the sphagnicolous or moss habitats of fens, bogs and marshes, the presence or absence and amount of peat (Godeanu, 1973), the water source and circulation (Godeanu, 1973) and the availability of foreign inorganic test building materials (Heal, 1961) influence the composition and distribution of the testate fauna. In alpine soils where the geological base is significant in plant distribution, the vegetation (including its litter) is of greater importance perhaps than is the source of the soil parent material in testacean community structure (Laminger, 1971a; Rosa and Lhotsky, 1971). However, Bonnet (1961a) developed a formal classification (Table I) of the testacean communities of mineral soils from an altitude of 2000 m in the Pyrenees. In young or immature soils (skeletal or azonal) the fauna was related to the kind of parent material or parent rock, and consisted largely of Centropyxidae. In zonal or mature soils the fauna was independent of the parent material and the most characteristic genus was *Plagiopyxis*. Laminger (1971b, c) found that different types of alpine lichens, mat and cushion plants have somewhat different testacean faunas.

In forest soils, while vegetation, soil moisture and pH are paramount environmental parameters, testacean ecology is affected as well by the nature of the overlying litter (Bamforth, 1967), different rates of decomposition of the litter (e.g., coniferous versus deciduous litter) (Bamforth, 1967; Stout, 1968), and different humus types (e.g., mull or mor) and their inherent biotic processes (Stout, 1963, 1968). A marked stratification in forest soils has been well documented for Testacea (Volz, 1951; Bonnet, 1961b; Schönborn, 1962; Coûteaux, 1972) and this marked distribution appears to be related to pore space, thickness of water film, resistance to desiccation, and availability of test building materials (Stout and Heal, 1967).

Species composition and distribution data can be used to classify the sites studied into groupings of similar habitats. Bonnet (1964, 1966a, b, 1967) used a method of multifactorial analysis to relate distribution of Testacea as a function of some physico-chemical soil characteristics and to establish a system of ecological groupings based on the environmental information. He has used his statistical techniques to describe several kinds of communities based on biogeographical, ecological and biocenotic relationships.

Coûteaux (1969) examined the species composition and distribution of Testacea in 59 habitats and calculated a statistic denoting the "degrees of preference" of each species for each habitat. However, her analysis of environmental parameters was not as intensive as that of Bonnet.

There is little information regarding species composition and distribution and community analysis concerning Testacea in Canada. Fantham and Porter (1945) listed the Testacea observed in many moss habitats in Eastern Canada and de Puytorac *et al.* (1972) presented an inventory of protists (including Testacea) in some soils in central Québec). This paper is the first analysis of Testacea in some Rocky Mountain soils.

Methods

The studies were carried out in the Kananaskis Valley (ca. 52°N, 115°4′W) in the front range of the Rocky Mountains of Alberta. The sampling sites were chosen from the Kananaskis Research Forest, Bow Forest Reserve and the Marmot Creek Watershed Research Basin.

Eight different sampling sites, one in each of the following habitats, aspen woodland (alt. 1400 m), fen mosses (other than *Sphagnum*) and fen *Sphag-*

TABLE I

Classification of testacean communities (from Bonnet, 1961)

Class	Order	Alliance	Association	
Soils in general *Phryganelletea*	Azonal soils low in organic matter *Centropyxidetalia*	Acid soils *Corythion dubii*	Soils with Saxicole vegetation and roots.	*Centropyxidetum deflandrianae*
			Skeletal soils	*Centropyxidetum vandeli*
		Calcareous soils *Bullinularion gracilis*	Soils very low in organic matter	*Paraquadruleto-Hyalosphenietum insectae*
			Soils with accumulated organic matter	*Centropyxidetum plagiostomae*
			Decalcified clays	*Pseudawerintzewietum calcicolae*
			White rendzinas	*Geopyxelletum sylvicolae*
			Skeletal soils	*Arcelletum arenariae*
	Evolved soils rich in organic matter *Plagiopyxidetalia callidae*	Brown forest soils *Plagiopyxidion callidae*	Mor	*Plagiopyxidetum callidae*
			Mull	*Plagiopyxidetum penardi*
		Grassland soils *Tracheleuglyphion acollae*	Humic alpine soils	*Tracheleuglyphetum acollae*
			Calcareous grasslands	*T.a. centropyxidetosum elongatae*
	Saline soils	Saline soils	Saline greys	*Centropyxidetum halophilae*

num (1400 m), spruce forest (1890 m), pine forest (1400 m), *Phyllodoce* alpine meadow (2590 m), *Kobresia* alpine meadow (2500 m) and grassland (1460 m) were selected. Soil references and vegetation types for the sampling sites are given in Table II.

To determine the species composition and distribution of Testacea in some Kananaskis soils, 20 soil cores and a block of soil 50 cm × 50 cm × 20 cm deep were taken from each site after a visual assessment of the chosen sampling sites. Ten cores were used for the preparation of slides by the Coûteaux (1967) technique, with 4 replicated slides prepared for each layer, and the other 10 cores were used for culturing (after Heal 1964). The soil blocks were used to prepare soil extracts to be used as culture media. A soil profile description was made for each site from the cores and blocks taken from the sites (Table III). (Profile description follows "The System of Soil Classification for Canada", 1970, Canada Dept. of Agriculture, 249 pp.).

From the prepared slides the number of living individuals (active plus encysted forms) was determined for each species found in each layer in each soil. The cultures prepared were used to enumerate number of species in each layer in each soil and to make positive identification of the species.

Results

The results of the principal investigation are shown in Table IV, with the number of individuals per species of Testacea in a given layer being expressed as a percentage of the total number of individuals per layer. The numbers of individuals counted in the different samples were summed and the composition of species in percent in every layer in each habitat calculated. Only active and encysted individuals were counted.

The table contains 42 species and varieties and 2 species groupings (*Euglypha* complex and *Euglypha* complex forma *glabra*). Less than 10 individuals were recorded in 18 species and vari-

TABLE II

Soil references and vegetation types for eight Kananaskis Valley soils

Habitat	*No. of spp. Testacea*	*Soil reference*	*Vegetation type*
A. Fen Mosses	37	Hydric humisol organic (Karkanis, 1972)	Mosses (*Camyplium* sp. *Tomethypnum* sp.)
B. Fen *Sphagnum*	22	Hydric humisol organic (Karkanis, 1972)	Moss (*Sphagnum* sp.)
C. Spruce Forest	18	Orthic humo-ferric podzol (Karkanis, 1972)	*Picea-Abies/Menziesia-Lycopodium*
D. Pine Forest	21	Mini humo-ferric podzol (Karkanis, 1972)	*Pinus-Populus/Aster-Galium*
E. *Phyllodoce* Meadow	14	Lithic regosol (Karkanis, 1972)	*Phyllodoce*
F. *Kobresia* Meadow	18	Lithic dark brown chernozemic (Kirby and Ogilvie, 1969)	*Kobresia-Dryas*
G. Grassland	17	Orthic dark brown chernozemic	*Agropyron-Bromus-Phleum/Dodecatheon-Galium-Delphinium*
H. Aspen Woodland	27	Orthic gray luvisol (Karkanis, 1972)	*Populus/Thalictrum-Epilobium-Rosa*

TABLE III

Descriptions of the organic layers of the soils in the sampling areas.

Soil	*Horizon* *Depth* *pH*	*Description*
Aspen Forest	A_0L 0-2 cm 6.4	Distinct litter of leaves (aspen, herb, grass), petioles and wood material; some leaves near bottom exhibit fenestration; fungal mycelia, few faecal pellets present; few pine and spruce needles; compact layer.
	A_0F 2-3 cm 6.4	Smaller litter fragments; large degree of fenestration; much fungal mycelia and many faecal pellets; a few roots present.
	A_0H 3-6 cm 6.6	Amorphous, greyish-black, finely divided organic material; occasional litter fragment; abundant mycelia, faecal pellets and roots; occasional small stones.
	Ah 6-7 cm 6.7	Transition of humus to mineral layer; amorphous, very finely divided organic matter mixed with mineral materials; more visible root and mycelial material than A_0H; greyish-black; a few small stones.
	A 7 cm ↓ 6.7	Greyish-brown, crumbly mineral material; many small stones; many larger roots present; material much drier than A_0H or Ah.
Fen Mosses	(A_0L) L 0-3 cm 6.4	Moss cover; distinct litter of birch leaves; some aspen leaves, pine and spruce needles, and grass blades; some areas always waterlogged; few faecal pellets.
	(A_0F) Of 3-5 cm 6.6	Fibric layer; smaller, distinct litter fragments; small roots present; almost always waterlogged; some black organic matter near bottom.
	(A_0H) Om 5-7 cm 6.6	Mesic layer; finely divided organic material, occasional litter fragments; many small roots and some larger *Betula* roots; always waterlogged; mixture of black humus, sand and clay.
	(Ah-A) Oh 7 cm ↓ 6.8	Humic layer; black mixture of organic material; sand, clay; large *Betula* roots; few stones; always waterlogged.
Fen *Sphagnum*	(A_0L) L 0-4 cm 6.4	Green *Sphagnum* cover; less tree litter than in other fen mosses; grass litter plentiful; some *Equisetum* litter; some faecal pellets; grass and *Equisetum* roots plentiful; never waterlogged; *Sphagnum* areas in mounds around *Betula* clumps and pine shrubs.
	(A_0F_1) Of_1 4-9 cm 6.4	Fibric layer; light brown *Sphagnum* fragments; some leaf litter, large and small, incorporated; grass and *Equisetum* roots throughout; few faecal pellets; *Sphagnum* segments intact; some mycelia; few larger *Betula* roots; never waterlogged.
	(A_0F_2) Of_2 9-22 cm 6.8	Fibric layer; dark brown to black *Sphagnum* fragments; most intact; some mycelia; leaf litter infrequent but mostly intact; some black organic matter — some grass and leaf litter is black and fragmented; few large roots *(Betula)* and few grass roots; waterlogged in spring and fall.
	(A_0H) Om 22-25 cm 6.6	Mesic layer; finely divided organic material interspersed with black *Sphagnum* segments, some small, some 2-3 cm long, and some intact leaf litter; only large *Betula* roots; always waterlogged; very little mycelia; some sand and clay mixed in.
	(Ah-A) Oh 25 cm ↓ 6.4	Humic layer; black, muddy mixture of organic matter, sand, clay; some stones present; always waterlogged; few large roots *(Betula)*.

TABLE III (continued)

Descriptions of the organic layers of the soils in the sampling areas.

Soil	*Horizon Depth pH*	*Description*
Spruce Forest	A_0L 0-1 cm 6.4	Moss cover; distinct litter of spruce and fir needles, woody material, ground flora leaves and stems; lichens abundant; some root material.
	A_0F_1 1-7 cm 6.8	Coarse litter fragments; brownish moss and lichen litter; many small roots and much mycelia present; black; faecal pellets abundant; woody material usually still intact.
	A_0F_2 7-13 cm 7.2	Fine litter fragments of needles and moss material; occasional pieces of soft woody material; roots and mycelia abundant; faecal pellets very abundant; layer very compact; black.
	A_0H 13-17 cm 7.1	Finely divided, amorphous organic matter; layer compact; occasional litter fragments; less visible root and fungal material than A_0F; faecal pellets abundant; charcoal black; few small stones.
	Ah 17-24 cm 7.1	Transition of humus to mineral horizon; black to yellowish-grey clay; abundant root material; some mycelia visible; mixture of fine amorphous materials; frequent small stones.
	A 24 cm ↓	Yellowish-grey clay and sand mixture; frequent small stones and occasional larger stones.
Pine Forest	A_0L 0-0.5 cm 6.5	Distinct layer of pine needle litter, some reproductive parts, few aspen leaves and few ground flora leaves and stems; some mycelia; frequent faecal pellets; layer not very compact.
	A_0F 0.5-2.5 cm 6.8	Coarse litter fragments; some reproductive parts, pine needles, fenestrated aspen leaves, short ground flora stem sections; few roots visible; large amounts of mycelia and faecal pellets; matting by mycelia gives compaction to layer; brown to yellowish-brown in colour.
	A_0H 2.5-3.0 cm 6.8	Layer sometimes barely visible; amorphous, finely divided organic matter, black in colour; no litter fragments evident; much mycelia and root material visible; high occurrence of faecal pellets; layer very compact.
	Ah-A 3 cm ↓ 7.0	Ah, when present, very thin layer of mixed amorphous organic matter and mineral particles; less mycelia and faecal pellets; roots visible; charcoal-black in colour; A layer yellowish-brown, crumbly mineral material with some sand; infrequent small stones; larger roots also infrequent.
Phyllodoce Meadow	A_0L 0-0.5 cm 6.5	Bryophyte cover; mosses and occasional liverworts; distinct litter of small surface vegetation leaves and stems; larger leaves (3 mm × 6 mm) present; very few faecal pellets; abundant seeds; some small stones; very dry, powdery.
	A_0F 0.5-1 cm 6.6	Brownish moss litter partially fragmented and some fragmented leaf and stem litter; abundant seeds; faecal pellets and small stones abundant; small roots present; greyish-black.
	A_0H 1-1.5 cm 6.8	Many roots and root hairs visible; amorphous, finely divided organic matter with occasional litter fragments; small stones abundant; many faecal pellets; very powdery, dark grey.
	Ah 1.5-20 cm 6.8	This lithic soil has very little pure A horizon; dark grey at top changing to brownish-grey at bedrock; great number of roots in top half, fewer in bottom half; many small and larger stones; soil material very dry, very powdery.

TABLE III (continued)

Description of the organis layers of the soils in the sampling areas.

Soil	*Horizon* *Depth* *pH*	*Description*
Kobresia Meadow	A_0L 0-1 cm 6.6	Few litter materials (leaves) covering a green moss layer; below green moss lies 0.5 cm of brown moss litter; some roots present; few small stones; frequent faecal pellets; very dry.
	A_0F 1-1.5 cm 6.7	Fragmented litter of varying sizes; roots present; frequent small stones; some fungal mycelia; dark brown; very dry and powdery.
	A_0H 1.5-2 cm 6.7	Finely divided, amorphous organic material; very dry and powdery; frequent small stones; many roots and root hairs; much mycelia; dark brown.
	Ah 2-15 cm 6.6	Sample not deep enough to find A horizon; finely divided, amorphous mixture of organic and mineral matter; many roots and root hairs; many small stones and frequent larger stones; dark brown changing to a lighter brown; some mycelia visible.
Grassland	A_0L 0-0.5 cm 6.6	Almost exclusively grass litter (leaves and reproductive remnants); dry matted layer.
	A_0F 0.5-1 cm 6.6	Litter fragments of all sizes; black layer; very dry and brittle; faecal pellets; some mycelia.
	A_0H 1-1.5 cm ↓ 6.6	Brownish-black layer of amorphous organic material; occasional litter fragments; many small roots; occasional small stones; many faecal pellets; more mycelia visible; very dry and powdery; somewhat compact.
	Ah 1.5 cm ↓ 6.8	Soil very hard and sampler went only to 10 cm; no A horizon visible; layer dark brown; dry, powdery; many roots, large and small; frequent small stones; mixture of finely divided organic and mineral material; occasional larger stones.

eties; 12 species and varieties contained between 10 and 20 individuals; 5 contained between 20 and 100 individuals; and 100 or more individuals were recorded in the remaining 9 species. These latter 9 species *(Trinema lineare, T. enchelys, Euglypha laevis, E. rotunda, Phryganella hemisphaerica, Corythion dubium, Assulina muscorum, Centropyxis aerophila* and *C. aerophila* var. *sphagnicola)* composed 79% (1700 of 2400) of the individuals observed on the Coûteaux slides, with *P. hemisphaerica, T. lineare, T. enchelys, E. laevis, E. rotunda, C. aerophila* and *C. aerophila* var. *sphagnicola* almost completely ubiquitous, *C. dubium* limited, and *A. muscorum* very restricted in distribution.

The information compiled in Table IV can be used to classify the different sampling sites or habitats into groups of sites based on the species lists for each habitat. The first step in this clasificatory procedure is to use an index giving a numerical value to the similarity between two habitats. Mountford (1962) proposed an index of similarlity (I) based on the logarithmic-series of distribution (after Fisher, Corbet and Williams, 1943), and given as the positive root of the equation:

$$e^{aI} + e^{bI} = 1 + e^{(a+b+j)I}$$

The index of similarity I is approximated for a pair of habitats by substituting

TABLE IV

Distribution of Testacea in the organic layers of some Kananaskis soils

Habitats: A-Fen Mosses; B-Fen *sphagnum*; C-Spruce Forest; D-Pine Forest; E-Alpine Meadow *(Phyllodoce)*; F-Alpine Meadow *(Kobresia)*; G-Grassland; H-Aspen Woodland.

Species	Mean Size (μ)	A_0L % of total no / sample										A_0F % of total no / sample									
		A	B	C	D	E	F	G	H	Σn	Σm	A	B	C	D	E	F	G	H	Σn	Σm
Arcella catinus	95	1	1	1	1		1	14		6	8				4	1	1	4	2	5	9
A. discoides	120	4	2							2	7	8	1							2	8
A. discoides var. *scutelliformis*	70	1								1	3	1								1	1
A. megastoma?	245	1								1	1										
Centropyxis aculeata	120	2								1	4										
C. aerophila	70	2	5	3	1	12	5	14	6	8	32	8	2	9	7	3	8	6	14	8	58
C. aerophila var. *sphagnicola*	55	2	2	3	1	28	6		4	7	32		2	9	10	11	7	8	4	7	51
C. sylvatica	95	1		2	2					3	8			1	3				3	3	6
C. cassis	65																				
C. discoides	200											1								1	1
C. minuta	50			1			4			2	6	1	1	4	3			2	1	6	10
C. plagiostoma	80														2					1	1
C. platystoma	50			1						1	1			2						1	2
Cyclopyxis eurystoma	55						8		1	2	13	1					3	2	2	4	8
C. eurystoma var. *gauthieriana*	80																				
C. kahli	90								2	1	2						1	2	1	3	3
Plagiopyxis callida	70															1			1	2	2
Hyalosphenia elegans	90	1	1							2	2	8	1							2	8
H. minuta	35		1																		
H. subflava	60	8	5						2	3	21		18						2	2	27
Nebela collaris	140											1								1	1
N. dentistoma?	115											1								1	1
N. lageniformis	135											4								1	3
N. nobilis?	175											1								1	1
Heleopera petricola	85	1							4	2	6	8	1	2						3	9
H. petricola var. *major*	130	1								1	1										
Quadrullela symmetrica var. *longicollis*	115																				
Paraquadrula irregularis	35																				
Phryganella hemisphaerica	40	3		10	1	40	15	29	10	7	49	2	6	6	6	69	5	18	10	8	126
Difflugiella oviformis	20	2	1			2	2	1		5	16	1	2	3	2	1	1	2	2	8	14
Assulina muscorum	45				39					1	102				3				1	2	3
A. seminulum	75				3					1	7								1	1	1
Corythion dubium	45			16	38					2	118			4	14					2	14
Trinema enchelys	60	20	19	20	2		2		25	6	149	8	12	16	11	4	3	8	27	8	87
T. lineare	35	15	27	23	1	6	46	14	22	8	167	4	27	28	15	3	59	16	22	8	209
Euglypha scutigera	75	1	1	1	6					4	18	4		2	11	2				4	15
E. tuberculata	70				4					1	11				2					1	1
E. rotunda	45	12	14	5	4	6	7	12	13	8	89	4	11	5	4	5	7	18	14	8	59
E. laevis	45	12	17	1	1	6	3	12	11	8	61	4	15	5	1	4	4	10	4	8	62
E. polylepis	60					1	3	4		3	4					2	2	4		3	3
E. strigosa	70	10	5							2	12	28	2							2	27
Euglypha complex[1]	90	4		3	1					3	11	1		2	2		1		2	4	6
Euglypha complex forma *glabra*[2]	85			3	2					2	9			3	2			2	1	4	5
Cyphoderia ampulla	110	1								1	2	4								1	1
Number of individuals		173	120	110	264	27	135	16	130		975	89	142	87	75	120	168	55	107		843
Number of species		22	14	15	16	8	12	8	12		33	22	15	17	18	12	13	14	20		37

Σn: Number of occurrences; Σm: Total number of individuals

[1] *Euglypha* complex includes *E. ciliata* and *E. compressa*

[2] *Euglypha* complex forma *glabra* includes *E. ciliata* forma *glabra*, *E. compressa* forma *glabra* and *E. strigosa* forma *glabra*.

TABLE IV (cont'd)

Distribution of Testacea in the organic layers of some Kananaskis soils

Habitats: A-Fen Mosses; B-Fen *sphagnum;* C-Spruce Forest; D-Pine Forest; E-Alpine Meadow *(Phyllodoce);* F-Alpine Meadow *(Kobresia)*; G-Grassland; H-Aspen Woodland.

Species	*Mean Size (μ)*	A_0H % of total no/sample										Ah % of total no/sample									
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Centropyxis aculeata	120																				
C. aerophila	70	3	6	9	3		8	6	2	7	19		13				4			2	4
C. aerophila var. *sphagnicola*	55	6		9	3		8	11	2	6	20		13				8	25		3	9
C. sylvatica	95							3		1	1										
C. cassis	65								2	1	2										
C. discoides	200																				
C. minuta	50	2			5	3	1	3	1	6	7					18	5	13		3	7
C. plagiostoma	80			20	5				2	3	6			25	8		8			3	8
C. platystoma	50	3	1	10					2	4	4										
Cyclopyxis eurystoma	55	9	18		3		2	3	2	6	17	33	25		8		2			4	5
C. eurystoma var. *gauthieriana*	80						2		1	2	2										
C. kahli	90	6	3			1	1	3		5	13		13				1			2	2
Plagiopyxis callida	70						1		2	2	5					9	2	75	2	4	5
Hyalosphenia elegans	90	1								1	1										
H. minuta	35	3			2				1	3	7										
H. subflava	60	6	13						9	3	12										
Nebela collaris	140																				
N. dentistoma?	115																				
N. lageniformis	135																				
N. nobilis?	175																				
Heleopera petricola	85		3							1	1										
H. petricola var. *major*	130																				
Quadrullela symmetrica var. *longicollis*	115	7								1	2										
Paraquadrula irregularis	35	1								1	1										
Phryganella hemisphaerica	40	20	22	20	20	56	2	11	16	8	75	33	25	25	8	18	4	38		7	13
Difflugiella oviformis	20	2	2	1	1	1	1	1	1	8	9										
Assulina muscorum	45	6								1	2										
A. seminulum	75	3								1	1										
Corythion dubium	45																				
Trinema enchelys	60	9	6	20	39	3	9	11	30	8	57		13	25	42	9	23		17	6	33
T. lineare	35	3	3	10	20	2	42	8	27	8	102			25	17	18	16		65	5	41
Euglypha scutigera	75					25	3	1		3	20						5		8	2	7
E. tuberculata	70																				
E. rotunda	45	6	3	2	5	13	31	2	7	39					8	18	8		8	4	11
E. laevis	45		3		3	2	7	11	7	6	21				8	9	13			3	12
E. polylepis	60							1	2	2	3						3			1	2
E. strigosa	70		16							1	4										
Euglypha complex[1]	90		1							1	1										
Euglypha complex forma *glabra*	85	3	1							2	3										
Cyphoderia ampulla	110																				
Number of individuals		39	39	15	46	69	142	44	68		462	3	8	4	12	11	76	8	38		160
Number of species		20	16	8	12	9	15	14	18		32	3	6	4	7	7	14	4	5		15

Σn: Number of occurrences; Σm: Total number of individuals

[1] *Euglypha* complex includes *E. ciliata* and *E. compressa*

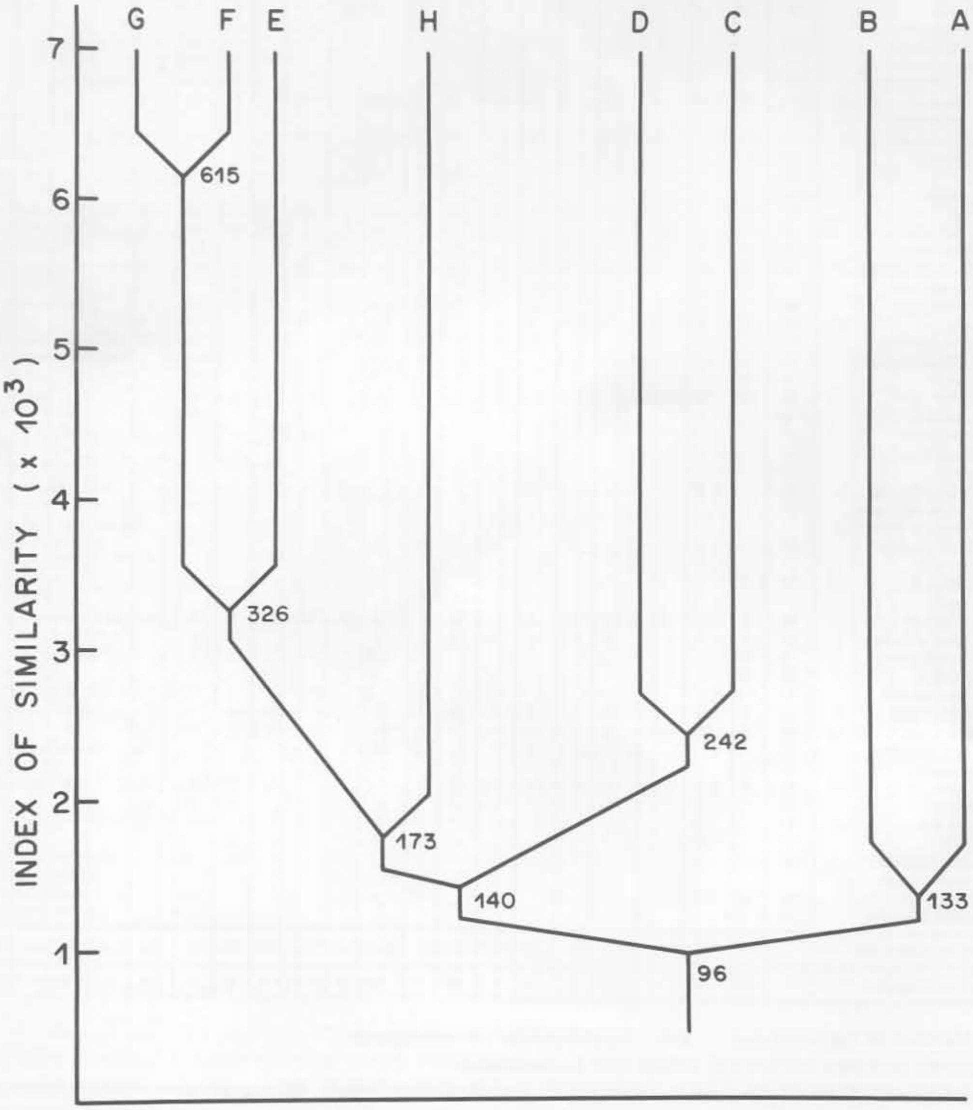
[2] *Euglypha* complex forma *glabra* includes *E. ciliata* forma *glabra, E. compressa* forma *glabra* and *E. strigosa* forma *glabra*.

the particular values of a, b, and j into the following equation:

$$I = \frac{2j}{2ab - (a + b)j}$$

where a = number of species found in the sample taken from site A,
b = number taken from site B,
and j = number of species common to sites A and B.

A matrix of indices was thus obtained for the relationship between habitats. Habitats with the highest indices were compared with other habitats, and a group index was obtained by directly averaging the aggregate of the indices of similarity. By working successively from higher to lower indices, a pattern of relationships was obtained between



Habitats: A - Fen Mosses; B - Fen *Sphagnum;* C - Spruce forest; D - Pine Forest; E - *Phyllodoce* meadow; F - *Kobresia* meadow; G - Grassland; H - Aspen woodland.

Figure 1. Classification of 8 soil habitat sites with the values given for the indices of similarity between sites and between groups of sites.

habitats respectively ranging from those closest together to those farthest apart. The relationships are graphically illustrated in the dendrograms (Figs. 1, 2, 3).

In the classification of the 8 different soil habitats studied in the Kananaskis Valley, there is a broad division into two groups (Fig. 1): the hydric humisolic fen soils in one group and the remaining 6 in the other. In the latter group of 6, there is a division between the soils of podzolic character (C, D), and the remaining soils (F, G, E, H), which illustrate transitional soil types, regosol, chernozem and luvisol. In terms of vegetative succession in south-central Alberta, the grassland and meadow chernozems can be changed to forest luvisols by the invading aspen trees (Pettapiece, 1969), and the regosols can be changed to podzols by further development and downslope movement (Millar, Turk and Froth, 1965). From Figures 2 and 3 it is evident that the general dendrogram pattern is followed in the A_0L and A_0F layers with the exception that in the A_0L layer, the highest degree of similarity is between the *Phyllodoce* meadow and the grassland soils. In the A_0H and Ah layers the pattern is lost and there are no evident trends.

Comparisons between the composition of the testacean fauna (expressed in percent) in the eight habitats show that the habitats can be classified into three different groups on this basis.

Group 1 consists of the two fen habitats, the *Sphagnum* and the other mosses. These habitats are characterized by three species exclusive to them: *Hyalosphenia elegans, Arcella discoides* and *Euglypha strigosa,* species preferring very wet habitats.

Group 2 consists of the two coniferous forest habitats, namely spruce and pine forests, which have one species exclusive to them: *Corythion dubium,* a common soil species reaching maximum numbers in forest soils.

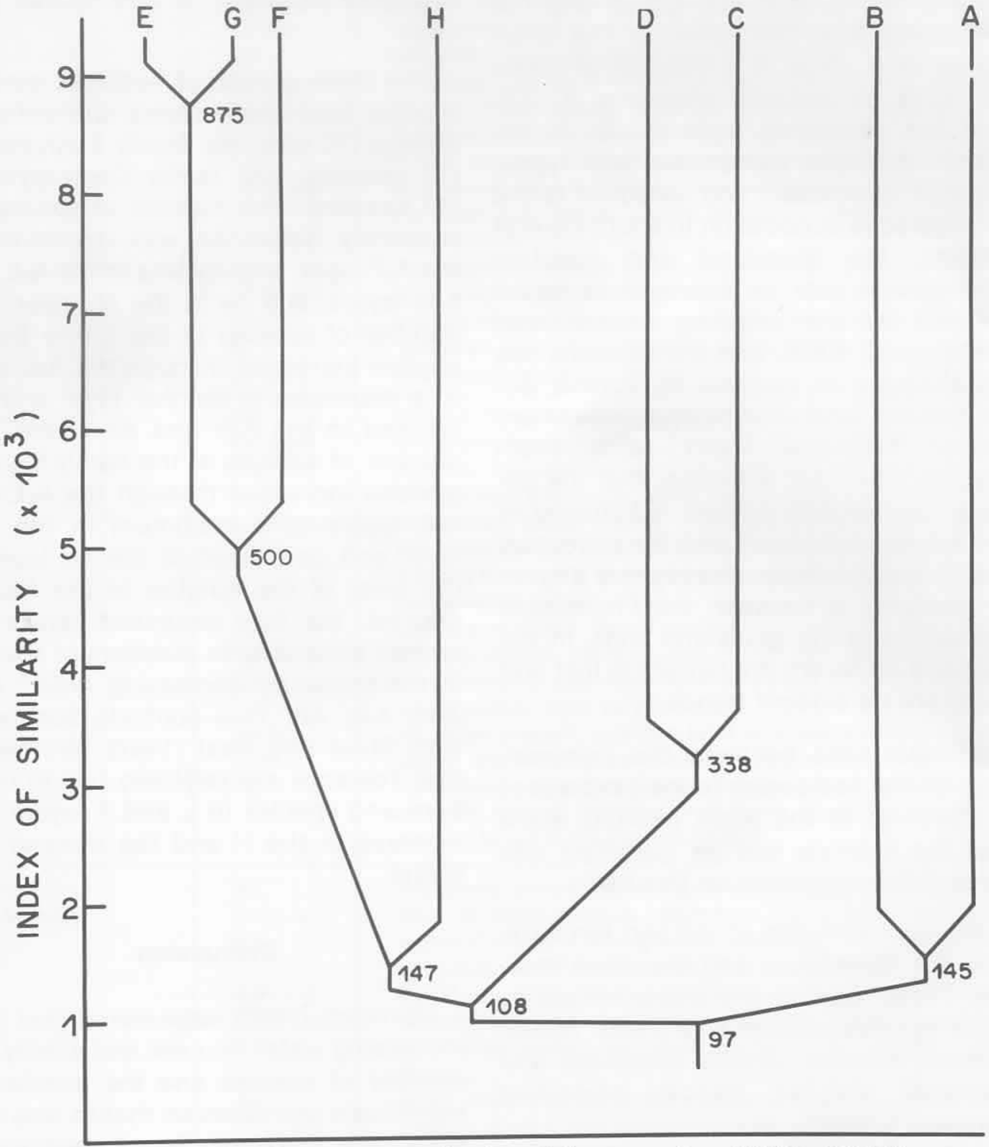
Group 3 consists of the remaining four habitats: grassland, *Kobresia* meadow, *Phyllodoce* meadow and aspen woodland, which have two species exclusive to them: *Plagiopyxis callida,* the typical terricolous species and *Euglypha polylepis,* a very sparse species.

The three groups of Testacea containing the most species were subfamily Nebelinae (10 species), family Euglyphidae (13 species), and family Centropyxidae (13 species). The number of species of subfamily Nebelinae was maximum in the A_0F layer, slightly less in the A_0L and A_0H layers, and nil in the Ah layer. The number of species in the family Euglyphydae increased through the A_0L layer to a maximum in the A_0F layer and decreased in the A_0H and Ah layers. The number of species of the family Centropyxidae increased through the A_0L and A_0F layers to a maximum in the A_0H layer and decreased in the Ah layer to the level of the number in the A_0L. In general, the four examined layers are ranked according to numbers of species in the following decreasing order: A_0F, A_0H, A_0L, Ah. This conflicts somewhat with Stout and Heal (1967) who stated that Testacea are relatively few in numbers and species in L and F layers and increase in the H and top mineral soil layers.

Discussion

Harnisch (1927) established that with increasing water content and acidity the number of species and the number of individuals increases so that in fens and bogs, the testacean fauna reaches its richest development. Considering the three habitat groupings based on species composition, an increase in the number of species from Group 3 to

Group 1 was observed in this investigation. The mean value for Group 3 is 19 species; Group 2 had a mean of 20 species; and Group 1 had a mean of 30 species; however, the differences were not significant. With the recorded pH range for all the various horizons of all the soils being 6.4 — 7.2, it seems possible to postulate that acidity plays a negligible role in testacean species composition and distribution in this study. It is therefore apparent that numbers and distribution of species could have been influenced by the increase in and permanence of the wetness of the habitat.



Habitats: A - Fen mosses; B - Fen *Sphagnum*; C - Spruce forest; D - Pine forest; E - *Phyllodoce* meadow; F - *Kobresia* meadow; G - Grassland; H - Aspen woodland.

Figure 2. Classification of the A_0L layers of 8 soil habitat sites with the values given for the indices of similarity between sites and between groups of sites.

The testate faunas of related soil types under different conditions of vegetation, weathering and podzolization can be compared (Table IV) and the effect of soil processes upon the character of the fauna can be judged. The dendrograms of Figures 1, 2 and 3 show the results of the groupings of habitats on the basis of the index of similarity analysis. Baltzer (1955) pointed out that the primary factors determining the faunal distribution in a number of soils

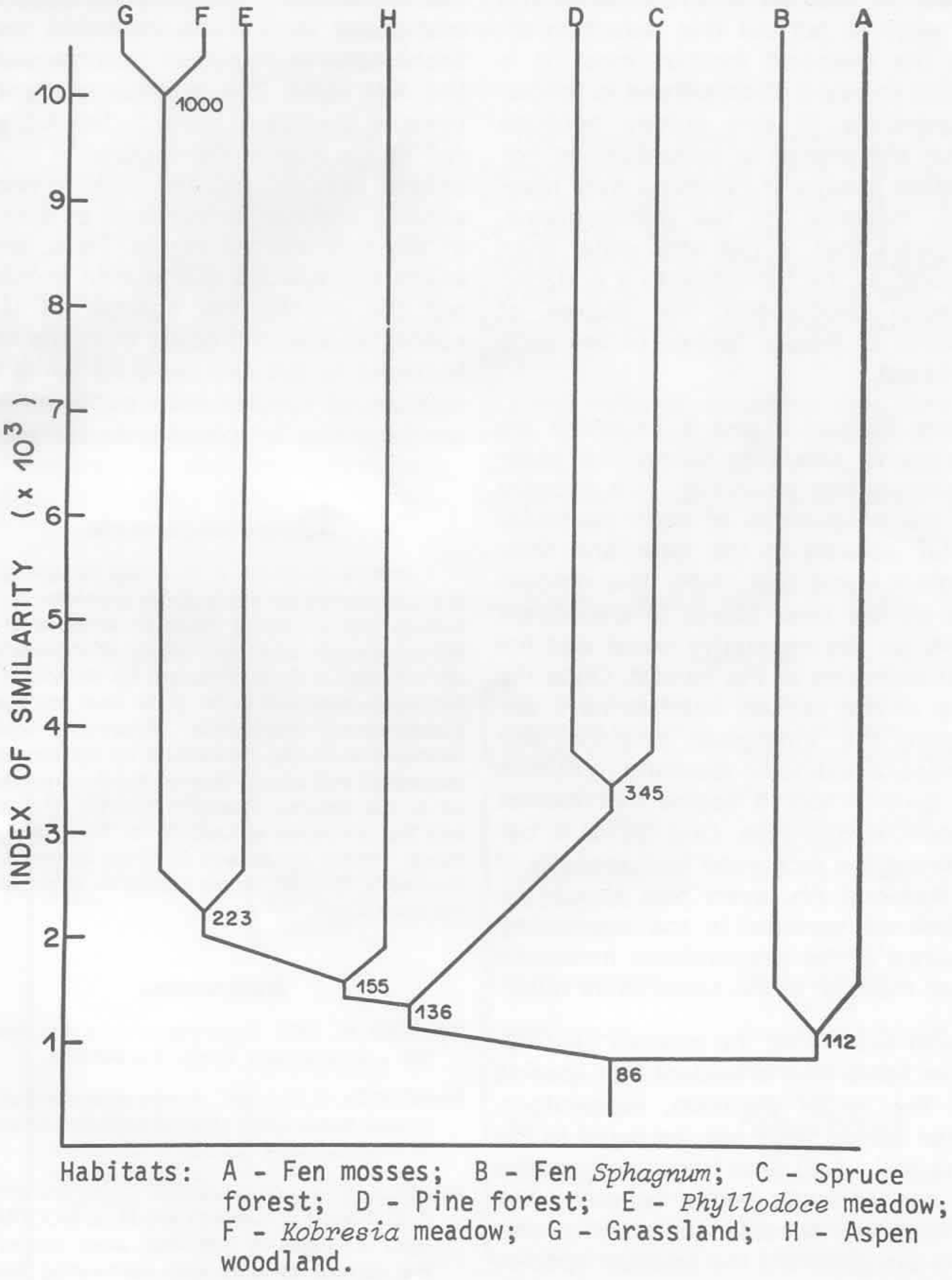


Figure 3. Classification of the A_0F layers of 8 soil habitat sites with the values given for the indices of similarity between sites and between groups of sites.

including rendzina, alluvial soils, brown earths, ground-water gleys, podzols, among others, are the calcium content and the water regime of the soil. Stout (1952) maintained that with increased leaching and podzolication the total number of species of Protozoa in the soil tends to fall but this reduction affects the rhizopod fraction most. It is difficult to say if such a trend is followed generally in this survey because neither the degree of podzolization nor the other groups of Protozoa were measured. However, in the dendrograms, it appears that in the soils other than fen soils, as the transition to a podzolic character progressed, the degree of similarity of testate faunas of the soils decreased.

From Figures 2 and 3, in which the patterns of similarity follow the same general pattern as in Fig. 1, it appears that the uniqueness of each particular habitat persists in the litter and litter fragment layers (A_0L, A_0F). This uniqueness of the litter layers is dependent mainly on the vegetative cover and the water economy of the habitat. Once the litters of the various habitats have undergone the biological, physical and chemical breakdown resulting in humus and mineral soil, it seems that habitat differences decrease. One factor in determining the increased homogeneity of the A_0H and Ah layers that should be considered perhaps is the over-riding influence of the predominant limestone parent material of the Kananaskis valley.

From examining the species distribution in Table III, it is evident that species with the larger pyriform, lagaeniform and/or spined tests are restricted to the layers (A_0L, A_0F) with larger soil spaces and consequently better aeration. The pyriform-test species found in lower layers are generally the smallest species of the representative groups (e.g., *Hyalosphenia subflava, H. minuta, Euglypha laevis, E. rotunda*) and these small species can usually fit their upright tests entirely within the water film around the soil particles. On the other hand, the species with globose, flattened, terricolous tests (Centropyxidae) constructed of sediment and mineral materials embedded in a thick chitinoid membrane achieve maximum occurrences in the A_0H layer. The number of Centropyxidae species is lower in the A_0L and A_0F layers than is the number of Euglyphidae species, but the Centropyxidae achieve equality in numbers of species in the A_0H and Ah layers. Thus, when examining species distribution throughout the profile, the number of terricolous species increases from the litter horizons to the soil horizons while the number of species with pyriform, lagaeniform and/or spined tests decreases.

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